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THE ROLE OF DATA IN DROUGHT PLANNING AND MANAGEMENT

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FOREWORD

The decade of the 1980s was characterized by frequent and widespread drought across the Canadian prairies. Despite major efforts to secure stable water supplies, instream and consumptive users both experienced serious shortages.

Managing the limited water resources of the Canadian prairies requires accurate and timely data and information on water quantity, quality and use. Data and information on current conditions and long-term trends are needed to reduce the effects of low flows, resolve problems of allocation, assess the sustainability of water systems and carry out integrated water resource planning. Data and information are fundamental to the development of preventive and mitigative responses to drought.

The following paper reviews the data collection programs of the Inland Waters Directorate, Environment Canada. Specifically, it describes how data contribute to drought forecasting, impact assessment, research and development, mitigation, institutional response and public information.

ACKNOWLEDGEMENTS

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1. INTRODUCTION AND BACKGROUND

The semiarid Canadian prairies have experienced periods of water shortages, or hydrologic droughts, throughout history. (Figure 1) As a result, a grassland ecosystem evolved which not only tolerates dry and wet cycles but depends upon these cycles to maintain its integrity.

During the last century, changes to the prairie landscape have greatly altered the natural ecosystem. Numerous dikes, dams, wells and diversions have been constructed to serve domestic, municipal, irrigation, industrial and recreational water needs. Many of these projects were designed without the benefit of adequate water resources information. In some cases, these projects have led to a deterioration in overall quality of the aquatic ecosystem.

The severe multi-year droughts during the 1980s reminded us of our continuing vulnerability to drought. As vulnerability is a function of both social and physical conditions, preventing or reducing drought impacts must bring together information from a wide variety of disciplines and agencies, including the Inland Waters Directorate (IWD), Environment Canada.

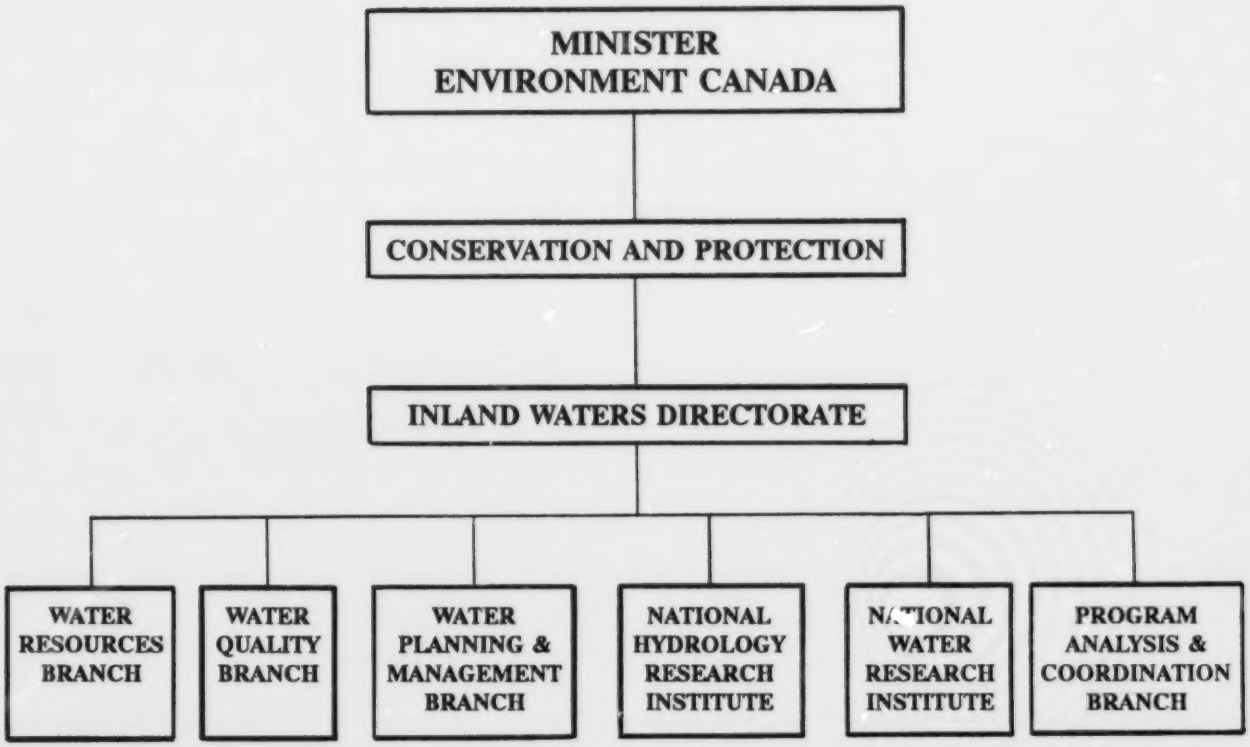
IWD has a major responsibility for the collection and distribution of water-related data within the federal government. In this capacity, IWD makes an important contribution to drought planning and management across Canada. Figure 2 illustrates the organizational structure of IWD, comprising an operational, administrative and research function.

This paper examines IWD's role in the collection of water quantity, quality and use data and the provision of information for drought planning and management. Specifically, the role of data and information is examined in terms of drought forecasting and early warning, impact assessment, drought-related research, institutional response, prevention and mitigation of losses and timely public information and education.

FIGURE 1
PRAIRIE REGION - CANADA

FIGURE 2

ORGANIZATION CHART
INLAND WATERS DIRECTORATE



2. DATA COLLECTION AND DISSEMINATION

In Canada, responsibility for water resources management is shared by the provincial, territorial and federal governments. IWD, the lead federal agency, plans and conducts federal, federal-provincial and international water management and research programs. The Directorate gathers data related to the quantity, quality and use of Canada's freshwater and monitors the aquatic environment in support of federal regulations. In carrying out its responsibilities, IWD works closely with provincial, territorial and U.S. water management agencies to ensure that water development is not detrimental to other jurisdictions.

Although operated separately, IWD's data networks for water quantity, quality and use complement each other in terms of drought planning and management. The following sections describe the three networks in greater detail.

2.1 WATER QUANTITY NETWORK

The Water Resources Branch (WRB) of IWD collects hydrometric and sediment data at 2700 gauging stations across Canada, 1100 of which are in the three prairie provinces. (Figure 3) In addition, data for another 860 sites are contributed to the national program through special arrangements with provincial and private agencies. These arrangements are formalized through federal-provincial cost-shared agreements that also provide for joint planning and continued review and assessment of the data collection networks.

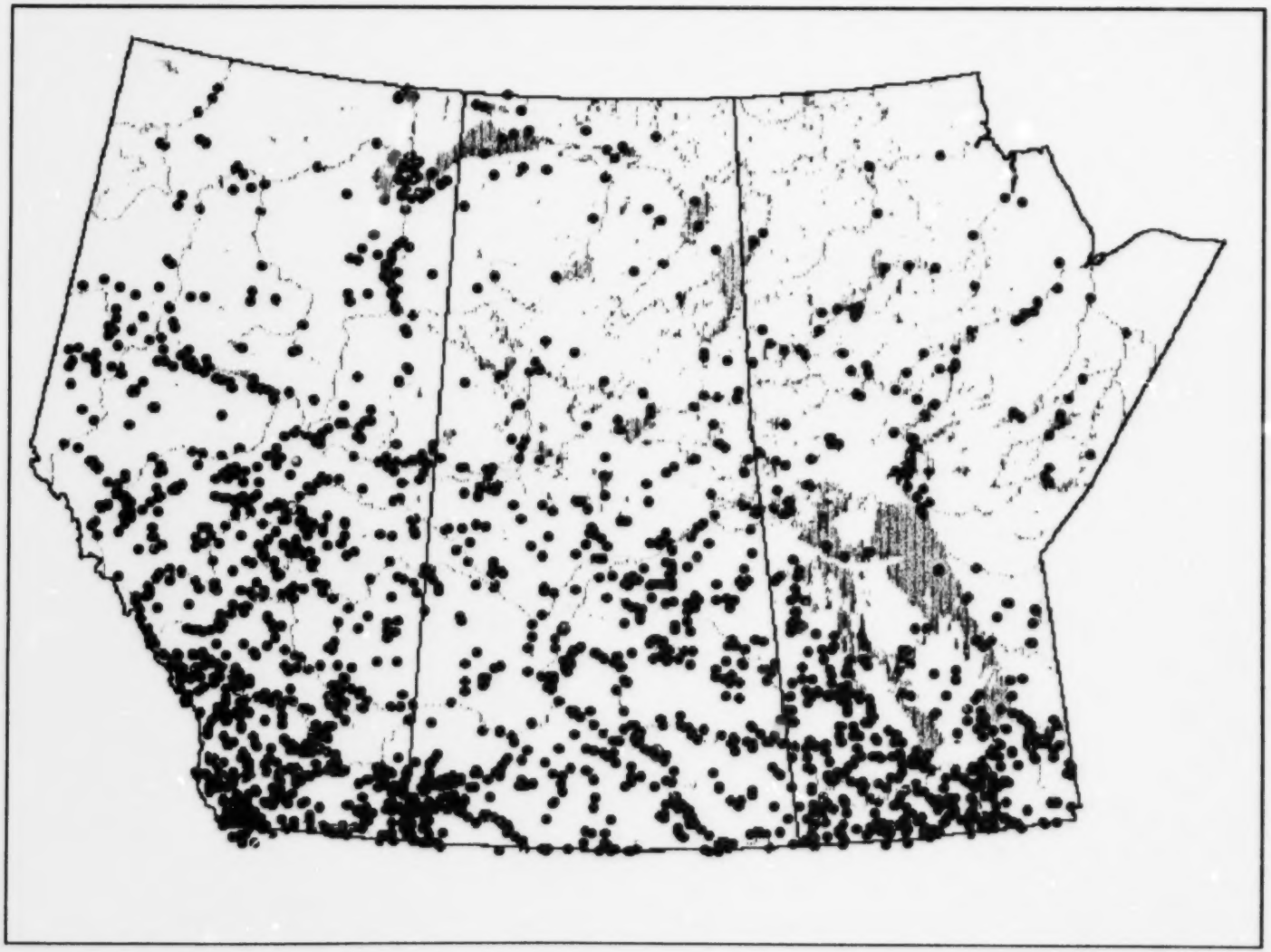
The mean density of the water quantity network in Canada is 13 stations per 100 000 people, or slightly greater than the comparable figure for the United States. The spatial density, however, is significantly lower at 0.4 stations per 1000 km^2. The period of record for the majority of sites is fewer than 25 years. Sites with the longest period of record, greater than 80 years, tend to be those situated along the Canada-U.S. border.

Water quantity stations can be grouped into two main categories, both of which serve drought planning and management.

a. The Water Management network provides at-site information for current operational purposes such as equitable apportionment of available water, flow forecasting, operation of control structures, specific basin studies and management programs.

b. The Hydrologic Inventory network provides data on the occurrence and distribution of stream flows in an area, maintains a basic knowledge about the nation's water resources and meets the need for water quantity data for a wide range of engineering, environmental and scientific projects.

FIGURE 3
FEDERAL WATER QUANTITY STATIONS - PRAIRIE PROVINCES



Source: Inland Waters Directorate - Environment Canada

Evaluation and planning to rationalize the network against present and future competing uses and demands and to ensure that the network is cost-effective is an ongoing activity. This process recognizes the interrelationships that exist with other data networks such as those for water quality and weather.

Availability and access to high quality surface water data are the foundation for good water resources management. Ensuring that users have ready access to data is an essential part of the WRB data collection program. To this end, WRB manages a national data base (HYDAT) of stream flow, water level and sediment data. These data are published in a regular series of data books consisting of annual summaries, historical summaries and reference indices. Data are also available on microfiche, magnetic tape and floppy disk.

An evaluation of the use of optical disk technology (CD-ROM) to disseminate hydrometric data has shown that this technology offers an effective alternative to data books and the centralized HYDAT system. The CD-ROM provides the entire historical data base for Canada in a readable and cost-effective format.

The recent availability of near real-time hydrometric data, defined as data that is received by the user within three hours of its collection, has improved the ability to assess the extent and severity of drought conditions and to make timely water management decisions. To improve real-time data collection, WRB has installed land-line and satellite telemetry systems in cooperation with other federal and provincial agencies and hydroelectric companies.

While no substitute exists for reliable, comprehensive water quantity data, hydrologic variables have been estimated using a variety of data transfer techniques. The WRB has also undertaken special studies to contribute to network evaluation and to provide hydrologic information. These studies recognize the linkages that exist with other data gathering networks and spatial information such as land use, land surface cover and social and economic information. GIS (Geographic Information System) technology is being used to integrate data and holds great promise for the future.

In addition to maintaining data collection networks and a data base, WRB contributes to water awareness and education. The availability and use of hydrometric data and information are enhanced through fact sheets, regular runoff conditions reports and reports of extreme hydrologic events, such as droughts.

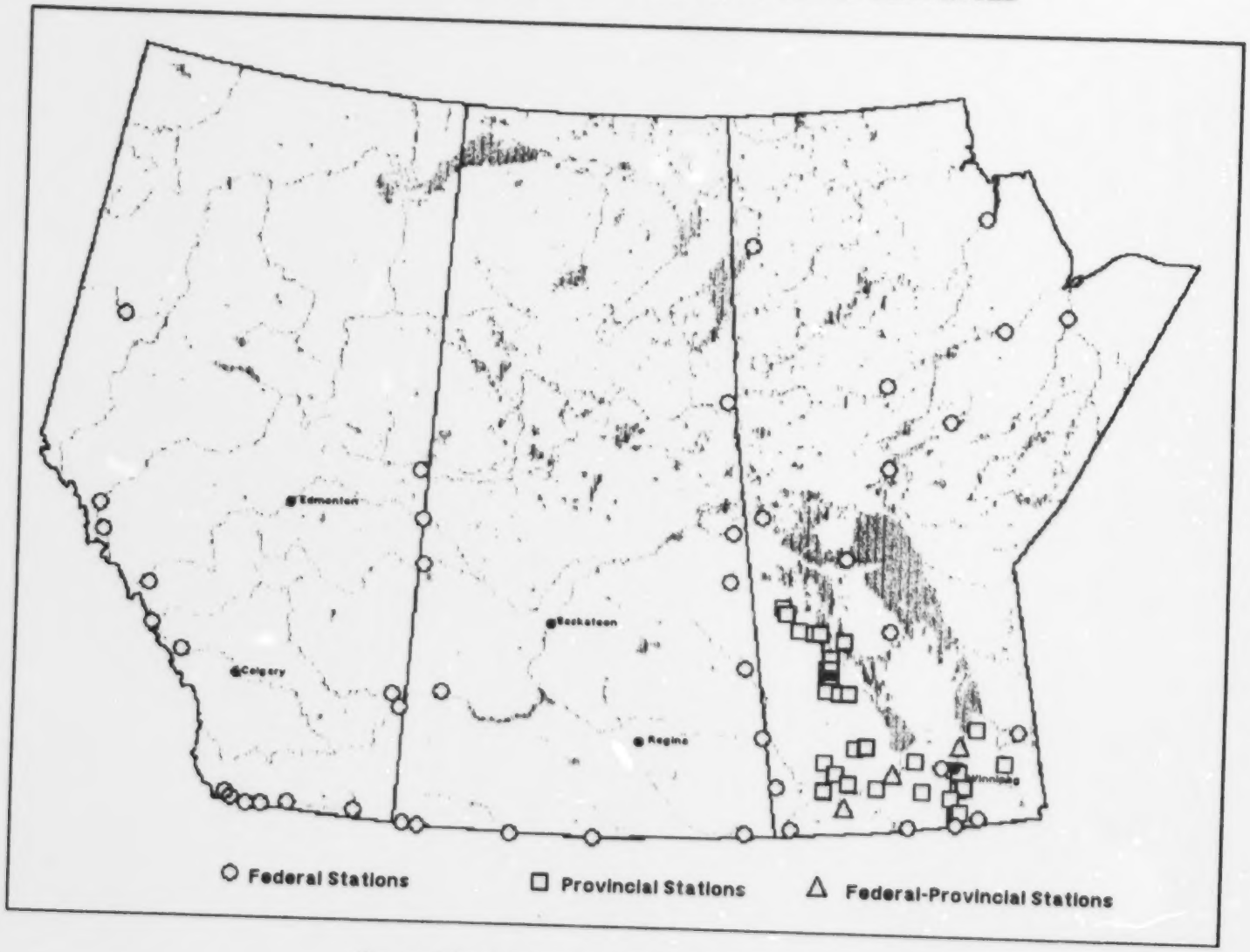
2.2 WATER QUALITY NETWORK

The Water Quality Branch (WQB) of IWD has developed an array of water quality monitoring programs which encompass over 500 sites across Canada. Approximately 40 sites are located in the three prairie provinces. (Figure 4) Most of the sites have been sampled on a long-term regular basis although the period of record is generally shorter than 15 years. Programs have emphasized baseline monitoring and trend assessment for major ions, nutrients, metals, pesticides and other toxic organic chemicals.

Monitoring activities are usually carried out through ad hoc and formal agreements or other types of collaboration with other federal departments, provincial governments and United States agencies. Cooperation with the provinces and the U.S. is coordinated by agencies such as the Prairie Provinces Water Board (PPWB) and the International Joint Commission (IJC).

Most of the data generated by WQB and other agencies are stored on NAQUADAT. The national data base resides in Ottawa but can be accessed in WQB regional offices. For each sample collected and analyzed, NAQUADAT contains information on sampling medium (e.g. water, sediment, etc.), location, time and analytical methodology used for each parameter. NAQUADAT permits the interchange of data as well as interactive retrieval of information (Water Quality Branch, 1986a).

FIGURE 4
FEDERAL WATER QUALITY STATIONS - PRAIRIE PROVINCES



Source: Inland Waters Directorate - Environment Canada

In addition to routine monitoring, WQB conducts short-term intensive surveys. The objective of such surveys is to document temporary but potentially significant changes resulting from natural or human causes. These surveys are usually issue-driven and focus on a limited number of relevant water quality parameters. For example, the WQB has studied changes in downstream water chemistry, resulting from releases from the Boundary Dam reservoir, on the Souris River under low flow conditions.

Modelling, in conjunction with the use of GISs, holds much promise as a forecasting tool to integrate water chemistry and biological data with other variables which affect water quality. For example, the long-term water quality data base for the Souris River basin is now being assembled for use in a computerized water quality forecast model. This model will facilitate the task of predicting impacts on water quality of large construction projects. A set of site-specific water quality objectives, developed with the most sensitive uses in mind, constitutes an effective tool for promoting water conservation and enhancing water quality. For example, an automated water chemistry monitoring station at Emerson, Manitoba, near the U.S. border, allows Canadian and U.S. agencies to observe, in near real-time, the effects of low summer and winter stream flows on water quality. The observation that dissolved oxygen concentrations were being affected, not only by climate but by human intervention, led to the implementation of effective corrective measures.

2.3 WATER USE NETWORK

In contrast to the water supply and water quality data collection systems, the water use data compiled by IWD are based on mailed questionnaire surveys of industrial plants and municipalities. The survey respondents, accordingly, are analogous to the spatial networks of the quantity and quality components of the IWD data system.

Industrial water use data have been compiled in Canada since 1972, with a four to five year periodicity. Completed survey documentation is available for 1972, 1976, 1981 and 1986. The size of the industrial survey "network" has grown from about 5000 respondents in 1972 to over 7000 in 1986. Water use data, collected from these 7000 respondents, constitute about 95% of total industrial water use in Canada. Respondent selection is done in consultation with Statistics Canada.

The municipal portion of IWD's water use data base includes all municipalities with over 1000 population. Again, data are collected by survey questionnaire. Data are available for 1976, 1983, 1986 and 1989.

The IWD municipal and industrial water use surveys include three dimensions: general socioeconomic data; physical data on the volumes of water used and data on water costs and/or water rates. General socioeconomic data on employment, value of shipments and population are included to tie the survey to economic trends. Physical data include

water intake and discharge figures, water intake by purpose or user group, water treated by method, sources of water intake, water recirculation and waste treatment. The industrial economic data deal with the costs of water acquisition, pretreatment, recirculation and waste treatment. For municipalities, the economic data include the retail water rates to residential and commercial customers and estimated total retail prices for both types of customers.

Currently, data are stored in a spreadsheet (LOTUS-123) format. Each year is dealt with separately without a computer link between them. This makes retrieval cumbersome. A National Water Use Data Base, NAWUDAT, to be operational in 1991, will store all of the data and simplify retrieval.

A second water use data base is operated by the federal-provincial Prairie Provinces Water Board. It includes water use data for the southern portion of the three prairie provinces on a five-year basis from 1951 to 1976 and annually from 1977 to 1986. Provincial water resource agencies provide data on water used for municipal, industrial, agricultural, power generation and recreational purposes.

The water use data program has been designed to facilitate analysis and interpretation. The aim of analysis and interpretation is to feed into Canadian water management decisions. While some basic research has been conducted, most analyses are of an applied nature to support broader water management studies.

Among the research projects undertaken are an analysis of the impacts of technological change on industrial water use, summaries of the data for each collection year and the compilation of industrial water demand functions. Applied analyses have included water demand forecasts for the Inquiry on Federal Water Policy, forecasts of consumptive water use for the IJC and an overview of municipal water rates and prices.

3. THE USE OF WATER RESOURCES DATA

Water resources data have played an important role in reducing the natural variability of water supplies for municipal, agricultural, industrial (including power generation) and instream uses in the Canadian prairies. Data and information on water quantity, quality and use have, more specifically, improved our ability to: (a) predict shortages and provide early warning to water users; (b) assess the impact of drought upon the environment and the economy, (c) carry out research into the relationships inherent in the hydrologic cycle under drought conditions, (d) develop appropriate government programs and policies which lead to more sustainable water use, (e) take action to prevent or reduce drought impacts through improved technology and (f) inform the public about current drought conditions and what can be done, either during or between droughts, to reduce impacts.

The role of water-related data in drought planning and management for each of these activities is discussed in the following sections.

3.1 DROUGHT PREDICTION / EARLY WARNING

Each year, outlooks for spring runoff are prepared by the three prairie provinces. Estimates are based on antecedent fall and winter precipitation, fall soil moisture conditions and ground water levels. Stream flow and climatic data are provided by Environment Canada to the River Forecast Centre of Alberta Environment, the Hydrology Service of the Saskatchewan Water Corporation and the Manitoba River Forecast Centre of Manitoba Natural Resources. Information is also provided by the U.S. National Weather Service, the U.S. Army Corps of Engineers, the U.S. Soil Conservation Service in Montana and the British Columbia Ministry of Environment.

Data on current stream flows and lake levels are available to the forecast centres in digital format. Information is summarized monthly, compared to long-term conditions and circulated to relevant provincial and federal agencies. IWD also provides timely input to the "Climate Extremes Committee" and other senior level interagency committees.

The Prairie Farm Rehabilitation Administration (PFRA), Agriculture Canada prepares the "Prairie Provinces Water Supply Conditions Report" based on information received from members of the Prairie Drought Monitoring Network. Reports are regularly updated March 1, May 1, July 1 and November 1. More frequent reporting occurs during periods of drought. Information on climate, hydrology, ground water, soil moisture, pasture and crop conditions and on-farm, community and urban water supplies is presented for Alberta, Saskatchewan and Manitoba. Water supplies are assessed in terms of present flows or levels, relationship to normal values, past trends and potential supplies. Actions taken to mitigate shortages are identified. Reports are distributed to members of the Prairie

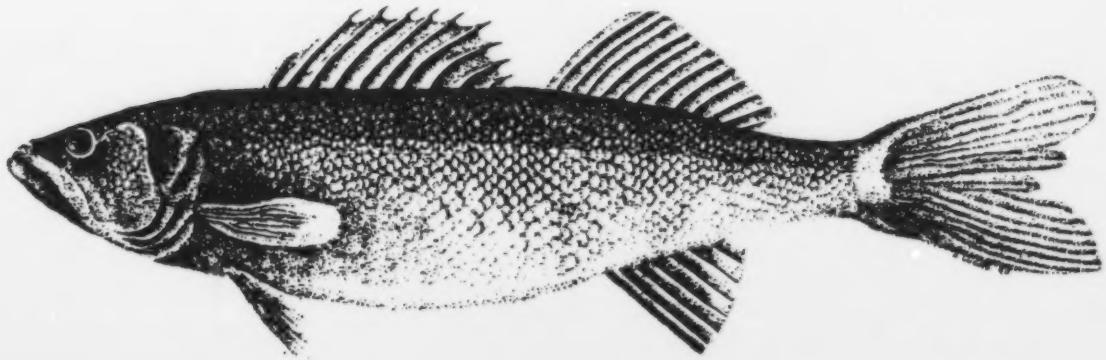
Drought Monitoring Network, senior federal and provincial managers and other water planners and managers.

3.2 IMPACT ASSESSMENT

Drought impact assessment is an essential part of drought planning. Knowing the social, economic and environmental implications of below normal water supplies and the risk of drought occurrence enables decision-makers to respond more effectively to drought.

Water-related data help predict ecosystem response and estimate the impact of an impending drought on water users. For example, reduced water quality associated with low flows adversely affects aquatic habitat and imposes limits on the use of water for domestic, municipal, irrigation, industrial and recreational uses. Studies on the relationships between water quality and low flows have been conducted for the South Saskatchewan River, Qu'Appelle River and Souris River.

The widespread drought of 1988 severely affected the entire prairie economy as well as the fish and waterfowl populations. To increase their understanding of drought impacts and relationships among climate, water and the economy, provincial and federal agencies participated in an assessment of impacts in Saskatchewan and Manitoba. (The report is scheduled for completion by December 1990.) Interpretation of water-related data was central to assessing impacts of the drought.



3.3 RESEARCH AND DEVELOPMENT

Research, conducted by the National Hydrology Research Centre (NHRC), IWD, has improved our understanding of the roles played by snow accumulation, glacial melt and evaporation on prairie water supplies. All three processes have particular relevance to hydrologic drought in the semiarid Canadian prairies.

The application of remote sensing to monitor snow cover, snowpack water equivalents and snowmelt events is currently under study. As snowmelt contributes a very large portion of flow in prairie rivers, more accurate predictions of streamflow will result from improved knowledge of snow conditions.

A second drought-related subject of research focuses on fluctuations in the area and volume of Canada's glaciers and the relationship of changes to hydrological and climatic records. An improved capability to analyze long-term changes in stream flow from glacierized basins will enhance our ability to determine base flows in major rivers crossing the prairies.

Open water evaporation is a critical factor in water resource planning and management in the prairies. Evaporative losses during droughts are often increased by accompanying higher temperatures. NHRC scientists have recently initiated research to improve evaporation estimates from lakes and reservoirs and to determine the influence of wind upon evaporation rates.

Research scientists can further contribute to drought impact reduction by ensuring that research findings are incorporated into policies and programs and that state-of-the-art technology is known to water managers and users.

3.4 INSTITUTIONAL RESPONSE

Water-related data have been used in the development of federal-provincial and international agreements governing the sharing of water in transboundary streams. During droughts, the availability of timely and accurate stream flow data are critical to ensure that 50 percent of natural flows are passed on to downstream jurisdictions. Timely water quality data are also essential to ensure that water quality objectives are met at boundary sites.

Data have been used as the basis for the development of long-term drought-proofing programs in the prairie region. For example, financial aid programs assist municipalities and farmers to develop secure water sources. Drought forecasts allow program managers to increase aid budgets in preparation for obtaining emergency water supplies.

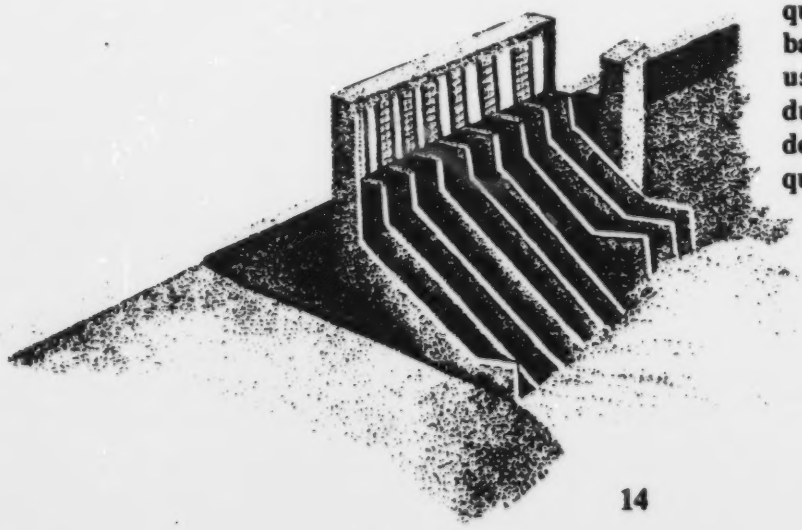
In recent years, efforts to protect and conserve habitat have increased. For example, cooperative programs have been developed to ensure that North American waterfowl populations are maintained and enhanced. As drought is a major factor in limiting habitat and reproductive success on an annual basis, forecasts of spring run-off are needed to estimate spring pond numbers. Stream flow data can also be used as proxy data for pond habitat conditions.

3.5 MITIGATION AND CONTROL

Real-time and long-term data are the foundation of drought mitigation and control. For instance, near real-time data allow water managers to make timely decisions to conserve scarce water resources through regulation of reservoir releases and water conservation practices. Long-term records describe variability of supply while statistical analyses, such as probability of occurrence, establish supply limitations. Low flow frequency analyses have been carried out for numerous monitoring sites in the prairies.

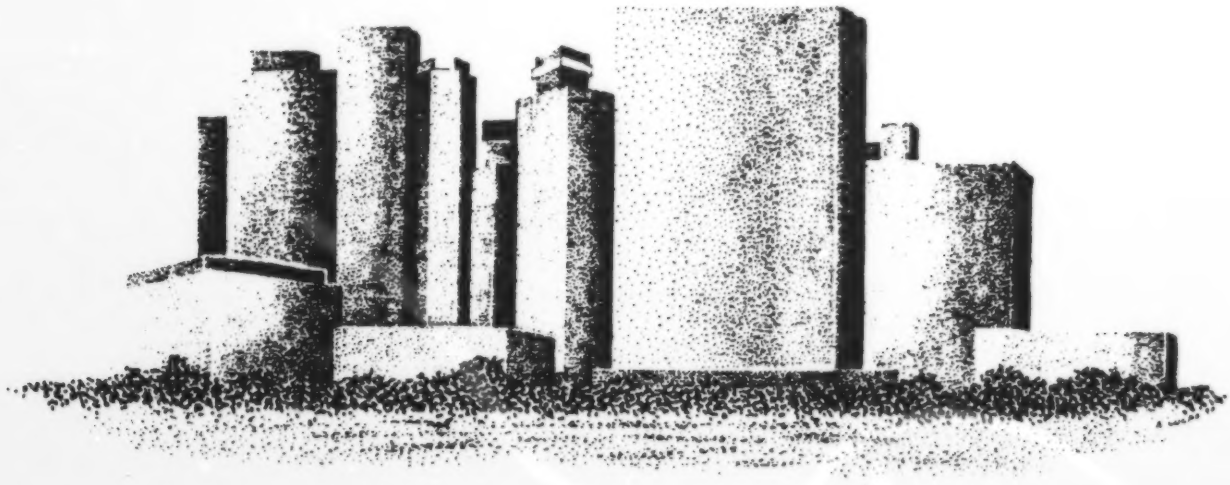
Supply management measures, such as construction of dams and pipelines, have been used traditionally to reduce variability of water supplies in the prairies. Rising costs of large water supply projects, a growing demand for limited water resources and environmental concerns now require managers and users to reduce demand through increased water use efficiency and other demand management practices. Data collection, analysis and dissemination are necessary under both supply and demand management approaches.

For example, current and historic data on water supply and demand are used in reservoir design and operation. Irrigation, the major water user in the prairies, depends on anticipated supply levels together with probability of rain and soil moisture at critical growth stages. Managing interbasin transfers, used to improve stability in the receiving basins, requires detailed information on flows, water quality and water use in both basins. Similarly, the conjunctive use of surface and ground water during prairie droughts again depends upon data related to quantity, quality and use.



3.6 PUBLIC INFORMATION/EDUCATION

A well informed public can contribute substantially to preventing or reducing drought impacts. Data agencies must, however, provide information in a form that can be readily applied by individuals to their specific needs. Individuals require timely forecasts and accurate information on present conditions during drought episodes. They also need information between droughts on what can be done to reduce drought vulnerability. Information has been provided to the public through fact sheets, displays, the media and participation at seminars, workshops and conferences.



4. SUMMARY AND CONCLUSIONS

Responsibility for water management in Canada is shared by provincial, territorial and federal agencies. The Inland Waters Directorate, Environment Canada has lead federal responsibility. The Water Resources Branch collects, interprets and disseminates standardized surface water quantity data and information in Canada in cooperation with the provinces and industry. All data are maintained in the data base, HYDAT. The Water Quality Branch monitors and assesses the quality of Canada's inland waters in cooperation with the provinces. Water samples are analyzed and data are stored in the data base, NAQUADAT. Water use data have been collected by the Water Planning and Management Branch since 1972. Data are currently available for municipal and industrial water use. A National Water Use Data Base, NAWUDAT, is under development and should be operational by 1991. The Prairie Provinces Water Board also maintains a water use data base for the southern prairies.

Long-term and real-time data on water quantity, quality and use help to prevent or reduce drought impacts. Accurate forecasts of impending water shortages permit users to adjust activities and behaviour to reduce water demands. Assessment of drought impacts upon the environment and the economy requires an understanding of the relationships between water quantity, quality and use. Knowing the implications of below normal water supplies enables managers to respond more rationally to drought. In the Prairies, water managers have traditionally responded to variable water supplies by constructing water supply projects. Recently, increased emphasis has been placed on reducing demands. Data are needed for both supply and demand management measures. Finally, meaningful information on regional water resources is required by the public, both during and between drought episodes, so that they can reduce drought impacts.

Our ability to maintain a sustainable balance between water supply and use is seriously tested during drought. Water resource data are especially valuable in (a) defining the natural limits and variability of supply, (b) developing environmental standards and ensuring that they are maintained under low flow conditions and (c) ensuring that limited supplies are allocated in an equitable manner. To deliver the greatest benefit, data must be reliable, timely, accessible and in a form easily used by the client.

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